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M804, 155 mm CAST TRAINING PROJECTILE BODY

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

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The M504, 155 mm projectile body is presently forged in steel. This program explores the possibility of using casting methods for producing the bodies and resulting in excellent cost savings. Inspection and testing during this phase of the program indicates that casting the bodies in ductile iron is a viable method of manufacture. Additional testing during the next phase is expected to result in type classification of cast ductile iron bodies for the M804 training projectile.

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INTRODUCTION

The Army has been directed by the Congress to conduct a demonstration of advanced casting technology in the production of artillery projectiles. In pursuit of this directive, the M804, 155-mm training projectile was selected for the demonstration program with an accompanying study to determine the feasibility of pursuing a similar program for the M107, 155-mm HE service round. The initial program (phase I) has been conducted under MT Task No. A5874873 under the auspices of Production Base Modernization Agency.

PROGRAM OBJECTIVES

Phase I, Manufacturing Methods Technology (MMT)

The objectives of the phase I effort were:

1. To demonstrate the feasibility and practicality of using cast bodies for artillery training projectiles in order to provide a multiple process production base leading to considerably reduced procurement costs. During the initial phases of this program, emphasis was on selecting materials and fully describe the manual casting processes with inspection procedures to assure consistent quality products.

2. To conduct a thorough paper study to determine the feasibility of using cast bodies for the M107, 155-mm service projectile.

Phase II Production Improvement Program (PIP)

The objectives of the phase II effort are:

1. Produce cast bodies on a semi-automated line

2. Document the process and inspection/test criteria

3. Finalize the TDP for cast projectiles

4. Conduct tests for type classification

5. Release the TDP for production

BACKGROUND

The following information is extracted from a report by T.E. Doran and O.J. Huey, Naval Surface Warfare Center, Dahlgreen, VA.

Orginally all projectiles were cast. However, early in the century, higher velocity and longer range requirements needed higher breech pressures to propel the projectiles. This meant that the gun luanched projectiles were now subjected to, and had to withstand, greater stresses for longer durations of time.

Projectile castings, at the time, were made of either cast iron or cast steel and were not capable of withstanding the higher stresses nor did they provide the toughness needed for gun launch. Therefore, the forging process replaced the casting process. Presently, there is a large data base on forging requirements and the process is well documented.

During the 1950's, reports filtered back from medical officers near the front lines in Korea, that considerable and unusual amounts of damage to personnel was being sustained by our troops from fragments emanating from Chinese and Russian cast artillery and mortar projectiles. The Army undertook an investigation of cast projectiles and verified the increased fragmentation effectiveness of cast ordnance. The yield strength and elongation was below the requirement for gun luanch.

In the mid-1960's, investigations using pearlithic malleable cast iron cylinders, demonstrated superior fragmentation characteristics and, therefore, better effectiveness. The reported increase in lethality was due to a larger number of lethal (50 to 100 grain) fragments than achievable with forged projectiles. This same study also indicated that an increase in lethal area could be expected with an increase in projectile wall thickness. This is not true of forged projectiles.

During the 1970's, a considerable amount of time and energy by the Navy was devoted to the investigation of the use of cast steel projectiles for the Navy's 5 inch/38, 5 inch/54 and 8 inch/55 guns. It was determined at that time, from the units that were fired, that the cast projectiles were equivalent to forged projectiles on a ballistic range and has 33% greater fragment mass. A synopsis of the Navy finds were:

1. Gunfire and recovery tests indicated that 5 inch and 8 inch projectiles could be produced in quantity that could withstand proof-pressure conditions. The cast projectiles were equivalent to forged projectiles on ballistic range, velocity, and inspection.

2. The cast projectiles had 33% greater fragement mass, more fragments in the 50 to 150 grain area, and retained 12% higher velocity at 100 feet as compared to fragments from forged projectiles.

3. The reports also indicate that 5-inch and 8-inch projectiles could be produced for 25 and 50% less, respectively, than forged projectiles when ordered in large quantities.

The casting program never reached production due to the inability of the industrial base to produce larger quantities of acceptable projectiles.

Improvements and advances in casting technology have occurred over the past several decades which make available the production of large quantities of quality projectiles. Although many improvements have been made in the reliability, accuracy, and lethality of present day projectiles, less emphasis has been placed on reduction of projectile costs. Since the technology is now available, the Army initiated this program to prove the feasibility of production and to develop the required technical data to procure.

PROGRAM DESCRIPTION

The cast M804, 155-mm training projectile program is a three year, two-phase effort to determine the ability of the cast bodies to withstand gun launching and develop the requirements for cast projectiles, verify performance, develop inspection procedures and criteria, prepare the technical data package for procurement, and perform the testing necessary for type classification.

Phase I was a dual concurrent effort to determine the feasibility of casting large caliber projectiles and determination of the most viable, both technically and economically, material, cast ductile (nodular) iron, or cast steel. A total of 500 rounds of each material were fabricated, assembled, and delivered for inspection and testing. Sixteen rounds of each material were randomly selected for firings, eight at low pressure and eight at high. The low pressure firings were to assure clearing the gun while the high pressure firings were to determine casting integrity. Eight rounds from each contractor were selected for drop testing from 7 feet. Four rounds of each material were cut to permit inspection of the internal finish, dimensions, and wall thickness variations. Another four rounds were dimensionally inspected externally. All projectiles from each vendor were x-rayed for flaws. Four cast ductile iron bodies were conditioned at -60°F for 48 hours and subjected to 7 ft trip drop tests and two rounds were conditioned at +145°F for 48 hours and were subjected to the same test. The six units were ultrasonically inspected for cracks and crack propagation; none were cracked.

The phase II effort will be awarded to the contractor that:

1. Qualified without failure on the drop and firing tests

2. Has a low indication rate from the x-rays

3. Met the internal cast finish requirements

4. Maintained a low problem incidence during phase I

5. Indicated the best estimated cost savings for production

Phase II will consist of producing 2000 rounds and type classification testing. By the conclusion of this phase, a technical data package (TDP) will be available for procurement. It is anticipated that the TDP will be ready by 4 Q FY 90.

INSPECTION AND TEST RESULTS

X-rays

	Ductile iron	Steel
No. reviewed	250	543
No. with indications*		

* Indications were primarily cosmetic, being related to chaplet area in iron and internal finish in steel. Steel had eight definitive discontinuities. One was metallurgically evaluated and found to be related to process anomalies.

Visual Inspections

Ductile iron - Acceptable
Steel - Acceptable

Dimensions

Material	External	Internal
Ductile iron	Acceptable	Acceptable
Steel	Acceptable	Acceptable

Finish

Ductile iron	≤ 250 in cavity **
Steel	>> 250 in cavity **

** The 250-micro finish is the drawing requirement which must be maintained for H.E. rounds but is not an absolute requirement for training ammunition.

Magnetic Particle (at vendor)

Ductile iron--no indications of flaws were observed on a random selection of about 50 units.

Steel--refer to Metallurgical Evaluations subparagraph.

Seven Foot Trip Drop Test

8 cast steel (ambient)*
8 cast ductile iron (ambient)
4 cast ductile iron (-60°F)
2 cast ductile iron (+145°F)
* High and low temperature tests were not conducted with steel projectiles since the proponent withdrew from competition prior to the test date.

Steel (ambient)--no indications were found by magnetic particle inspection before or after the drop. Eight units were tested and inspected.

Ductile iron (all temperatures tested)--no indications were found by magnetic particle inspection before or after the drop. Eight units were tested and inspected.

Firing Tests, Body Integrity

Ductile iron--the projectile cleared the gun with an average pressure of 5,837 psi (Z2) and the body had no breakup with an averge pressure of 50,600 psi (Z8). Eight rounds were tested at each pressure range.

Steel--the projectile cleared the gun with an average pressure of 5,613 psi (Z2) and the body had no breakup with an average pressure of 50,006 psi (Z8). Eight rounds were tested at each pressure range.

Metallurgical Evaluations

Ductile iron--metallurgical examinations of the microstructures, nodularity, and tensile properties were all found to be acceptable.

Steel--during machining operations, seven steel projectiles were observed having flaws which appeared to be cracks. Upon metallurgical evaluation of one projectile, it was determined that the anomaly resulted from slag inclusions caused by the casting process.

Costs, Estimated Production of 100 K/year*

Process	Cost each	$Savings/100K
Forging	$112.99	
Cast Ductile Iron	78.23	$3.476 M
Cast Steel	94.00	1.899 M

Summary

	Cast Ductile Iron	Cast Steel
Technical feasibility	Low risk	Medium risk
Reproducibility	Excellent	Good
Cast cavity finish	≤250	>>250
Withstand launch	Yes	Yes
Cost	$78.23 each	$94.00 each

PROGRAM STATUS AND CONCLUSIONS

The phase I effort has been completed. Randomly selected rounds have been inspected and tested resulting in the following conclusions:

1. Both cast ductile iron and cast steel are technically feasible for use in the M804, 155-mm training projectiles. However, from a review of the x-rays and visual inspection, the cast steel tends to be a higher risk since the required cast finish was not achieved and reproducibility was not proven. The cast ductile iron was evaluated as a low risk with an acceptable cast finish and proven reproducibility.

2. Economically the estimated unit cost savings as compared to forged steel bodies are $18.99 for cast steel and $34.76 for cast ductile iron. These estimates are those submitted by each contractor. From these estimates, it is apparent that the greatest savings will be realized with the cast ductile iron.

3. From the Navy's reproducibility history of cast steel projectiles of the 1970's and the high rate of indications seen in the x-rays of this program, it is concluded that the cast steel industry still has a production reproducibility problem. While unacceptable projectiles can be ferreted out, the inspection costs could be prohibitive.

4. If cast projectile bodies are to be considered in the future for HE artillery projectiles, the cast finish of the cavity must be greatly improved in the steel castings. The cast ductile iron finish in the cavity is presently acceptable.

* All money in this report is in FY 88 dollars.

5. The production estimates provided by each contract, when compared one with the other, shows a decisive savings of cast ductile iron over cast steel.

RECOMMENDATIONS

Phase II should be awarded to the contractor that cast the phase I bodies in ductile iron. This recommendation is based on the ability to reproduce acceptable projectiles and the projected production costs. In addition, since the paper study of the M107, 155-mm HE project indicated feasibility, the cavity finish of the ductile iron has already met the present requirement of 250 microinches.

Based on the paper study of the M107, 155 mm HE projectile, a program should be prepared and submitted to develop a cast body for the HE round. In addition, training projectiles for the 105-mm and 8 inch rounds should be considered for cast bodies.

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